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Quarterly Specialized Report

Introduction to Critical Minerals: Ontario's Unique Position

2022 – 2023

OCI
Where Next Happens

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“The cars of the future will be built in Ontario from start to finish because we made a promise to support our auto sector.”[1]

—The Honourable Doug Ford, Premier of Ontario

“Through our Driving Prosperity auto plan, strategic investments across our integrated supply chains, and by reducing the cost of doing business in Ontario by nearly $7 billion annually, our government is staking Ontario's claim as a leader in the emerging North American EV battery industry.”[2]

—The Honourable Victor Fedeli, Ontario Minister of Economic Development, Job Creation and Trade

1. Introduction

Our world is fuelled by critical minerals. From antimony to zirconium, critical minerals are vital components of countless products and technologies. As such, the stability of supply chains essential to everyday life in Canada and around the world are highly dependent upon a reliable supply of critical minerals.

Critical minerals are playing a particularly important role in the clean energy transition, since they are required for the development of several technologies such as solar panels, wind turbines, and electric vehicle (EV) batteries. As the world strives to cut carbon emissions, demand for clean technologies—and the critical minerals on which they rely—is expected to grow substantially.[3]

Ontario is poised to be a key player in the clean energy transition—and specifically in the production of EV batteries—due to its robust mining and automotive sectors. The province has an abundance of naturally occurring critical minerals and well-developed mining infrastructure: there are currently 37 active mining operations throughout the province, 10 of which produce critical minerals.[4] As of March 2022, the province was home to approximately 146 early- and advanced-stage critical minerals exploration projects.[5] Several of these mines and development projects extract, or are exploring opportunities to extract, cobalt, copper, nickel, graphite, and lithium, critical minerals that are essential for EV batteries.[6] Moreover, the mining sector is supported by a demonstrated history of investment by both the government and the private sector.

The strength of Ontario's mining sector is matched by that of its automotive sector. Ontario is Canada's only producer of cars and trucks and is the only subnational jurisdiction in North America that is home to five original equipment manufacturers (OEMs). The province's automotive sector is fuelled by an integrated supply chain including over 700 parts firms and over 500 tool, die and mold makers.[7]

In addition to its proven track records in both mining and auto manufacturing, Ontario also has a supportive regulatory framework; an "open for business" attitude; a highly skilled workforce; and a commitment to practices that align with environmental, social, and governance frameworks. In an uncertain world, Canada's political and social stability and global trade network provide resilience for critical minerals supply chains vulnerable to unpredictable prices and disruptions.

With these strengths, Ontario is uniquely positioned to develop a thriving end-to-end EV value chain that stretches from critical mineral extraction, processing, and refining to battery production, battery use, battery repurposing, and battery recycling. This report presents an overview of critical minerals, highlights their role in EV batteries, and examines Ontario's existing strengths in the EV battery supply chain. This report also discusses some factors driving change within the broader EV ecosystem and identifies opportunities for Ontario to secure its role as a global leader in all stages of the EV battery lifecycle.

2. Critical Minerals

"Ontario has already established itself as a jurisdiction that promotes safe, sustainable, and responsible mining, making our province the benchmark for how the mining sector can work and very attractive for investment. What's more is that our clean energy grid means that minerals mined in Ontario have a lower carbon footprint than many of our competitors, and that fact should not be lost on environmentally conscious investors."[8]

—The Honourable Greg Rickford, Ontario Minister of Indigenous Affairs & Ontario Minister of Northern Development

This section defines critical minerals and provides examples of their use in various industries. Moreover, this section underscores the importance of critical minerals for meeting global EV battery demand.

Critical minerals overview

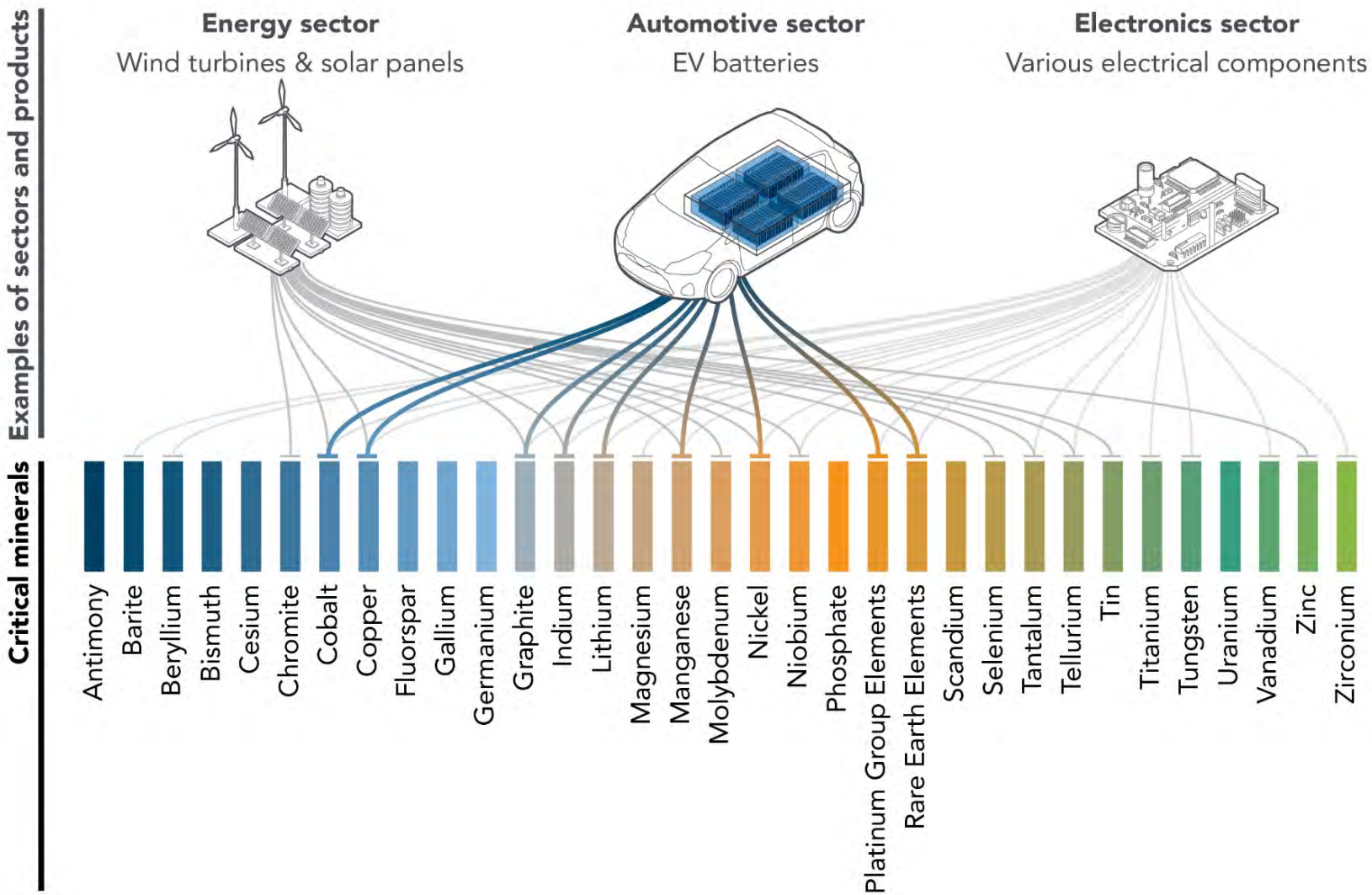
Critical minerals are minerals that play an essential role in the development of a broad range of strategic technologies with no viable alternatives. Critical minerals may also have a supply chain that is vulnerable to disruption. Jurisdictions around the globe have developed lists of critical minerals to guide strategic investments in mineral exploration and mine development. The list of so-called critical minerals varies depending on a jurisdiction's supply chain and development goals.

As provincial, national, and global priorities shift, so does the list of minerals considered to be critical.[9]

The Canadian federal government maintains a list of critical minerals, which are primarily identified based on their importance to Canada's economic security and their role in the transition to a low-carbon economy and sustainable development plans.[10]

Ontario also maintains a list of critical minerals. As described in its Critical Mineral Strategy, these critical minerals have exploration or development potential, strategic economic importance, application in technologies that support a low-carbon economy, or global market demand.[11]

The figure on the following page illustrates the critical minerals identified in Ontario's Critical Mineral Strategy and examples of sectors in which they are used.



Critical minerals identified by the Province of Ontario[12] and examples of sectors and products in which they may be used[13]
(Note: Links to various sectors and products are indicative)

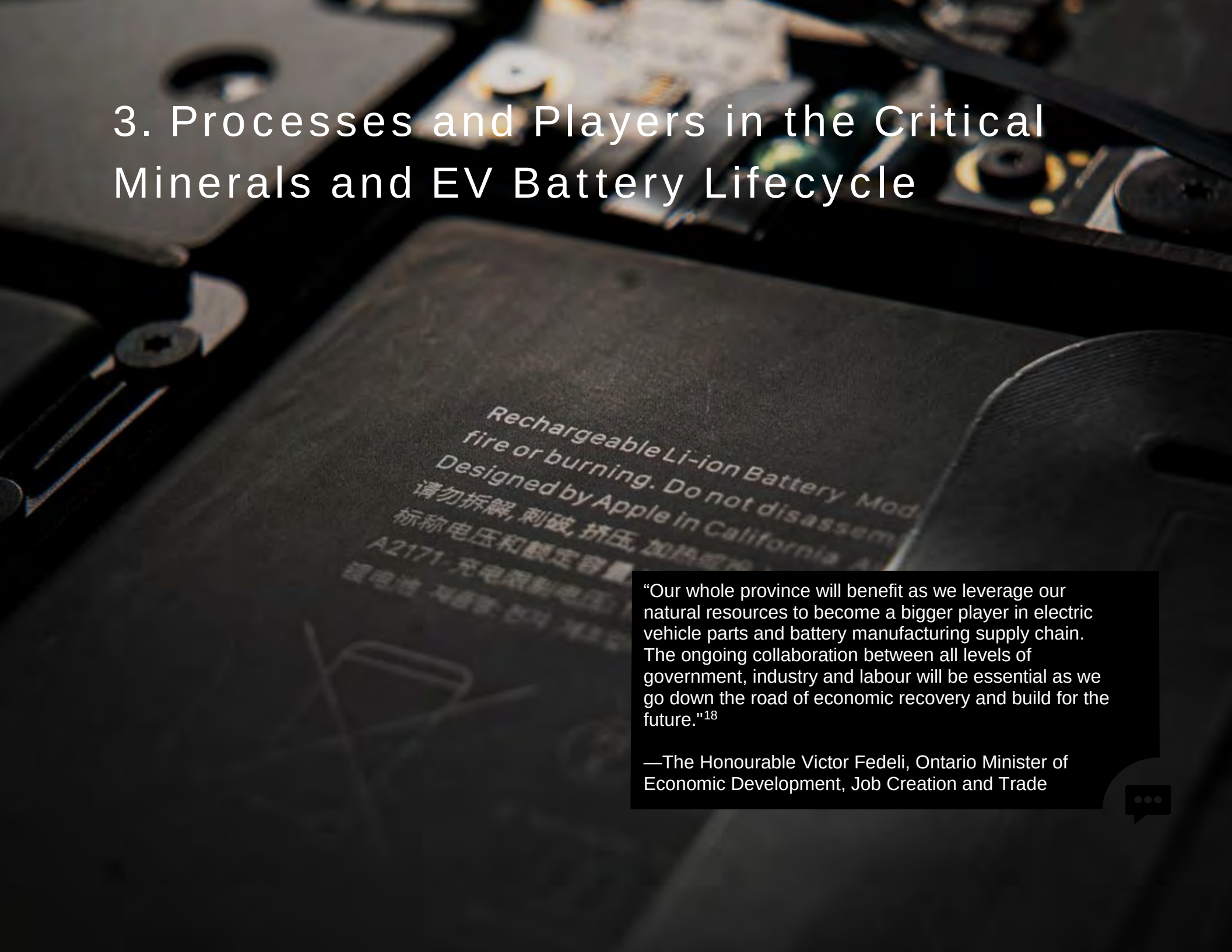
Critical minerals for EV batteries

EVs increasingly use rechargeable batteries as energy storage systems. The chemical reactions which power EV batteries depend upon an array of critical minerals, including, as of 2022, lithium, cobalt, graphite, manganese, and nickel.[14] The International Energy Agency estimates that an average EV requires six times as many minerals by volume as a conventional car.[15]

As demand for EVs grows, so will the demand for critical minerals. The International Energy Agency estimates that mineral demand for EVs will be 9 to 30 times larger by 2040.[16] However, increases in demand will not be even across all minerals. By 2040, the International Energy Agency projects that:[17]

- Demand for lithium could grow by up to 43 times;
- Demand for nickel could grow by up to 41 times;
- Demand for copper could grow by up to 28 times;
- Demand for graphite could grow by up to 25 times; and
- Demand for cobalt could grow by up to 21 times.

3. Processes and Players in the Critical Minerals and EV Battery Lifecycle



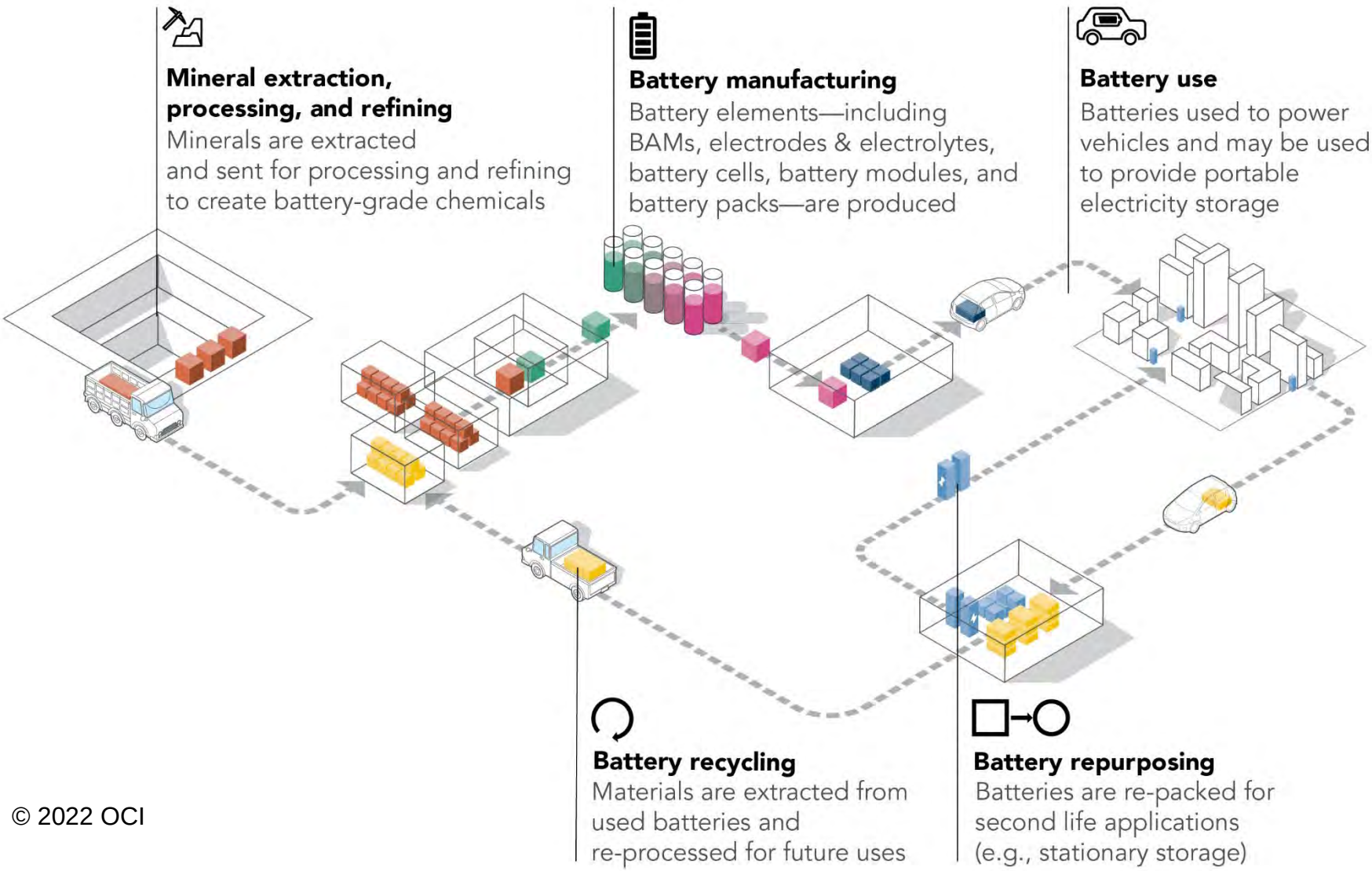
"Our whole province will benefit as we leverage our natural resources to become a bigger player in electric vehicle parts and battery manufacturing supply chain. The ongoing collaboration between all levels of government, industry and labour will be essential as we go down the road of economic recovery and build for the future."[18]

—The Honourable Victor Fedeli, Ontario Minister of Economic Development, Job Creation and Trade

Critical minerals are at the heart of the EV battery lifecycle, from mining to recycling. Ontario's EV battery lifecycle requires a broad range of actors—including multinational enterprises (MNEs), small and medium-sized enterprises (SMEs), start-ups, research groups, and other stakeholders—to ensure the robust, seamless, and economic production of batteries.

This section highlights the processes and players engaged in each stage of the EV battery lifecycle to facilitate understanding of the complexity of this ecosystem. Moreover, this section sets the scene for following discussions of drivers of change within the ecosystem and Ontario's unique position in the global market.

EV battery lifecycle



Overview of the EV battery lifecycle, including mineral extraction, processing, and refining; battery manufacturing; battery use; battery recycling; and battery repurposing

Mineral extraction, processing, and refining

The EV battery lifecycle begins with mineral extraction. To identify mineral deposits, mining companies undertake exploration projects. Identifying viable deposits can be a slow and difficult process: less than one in ten thousand exploration projects become mines.[19] Once a viable deposit is located, a range of pre-production activities—including consultation, analysis, planning, and financing—must be completed.

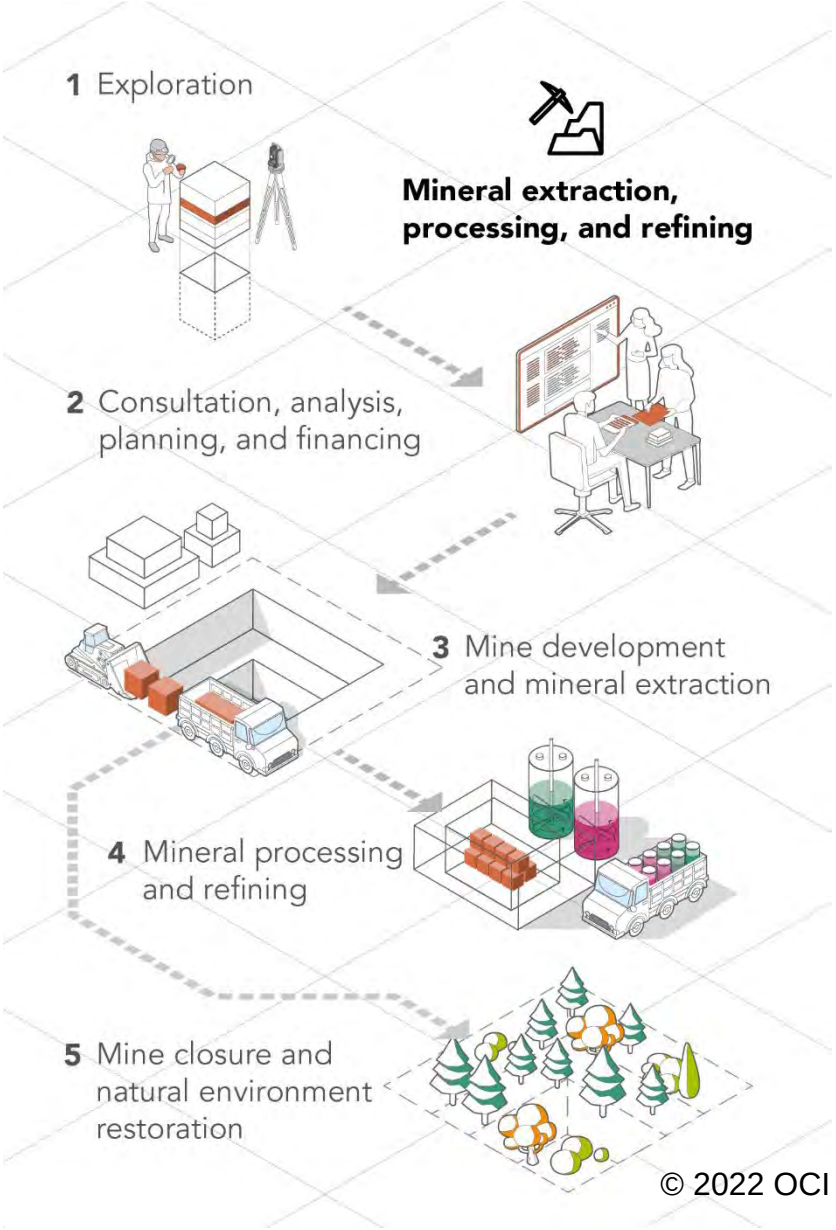
Once the necessary pre-production activities are completed, the mine is developed, and mineral extraction begins. Extracted material is then transported to refineries where the valuable minerals are isolated and processed using heat and chemical treatments into high-quality battery-grade chemicals.[20]

Planning for mines includes planning for their closure. Once mining activity ceases, buildings are dismantled, and the natural environment is restored.[21]

All stages of mine development are subject to extensive regulations and permitting requirements. In Ontario, 12 provincial and federal ministries regulate mining activities.[22]

Company Highlight: **Frontier Lithium**

Frontier Lithium, based in Ontario, is developing its 100%-owned lithium deposits in northwestern Ontario. The company aims to become a strategic domestic supplier of lithium salts and lithium hydroxide to support an increasingly local EV battery supply chain.[23]



Mineral extraction, processing, and refining lifecycle steps

Battery manufacturing

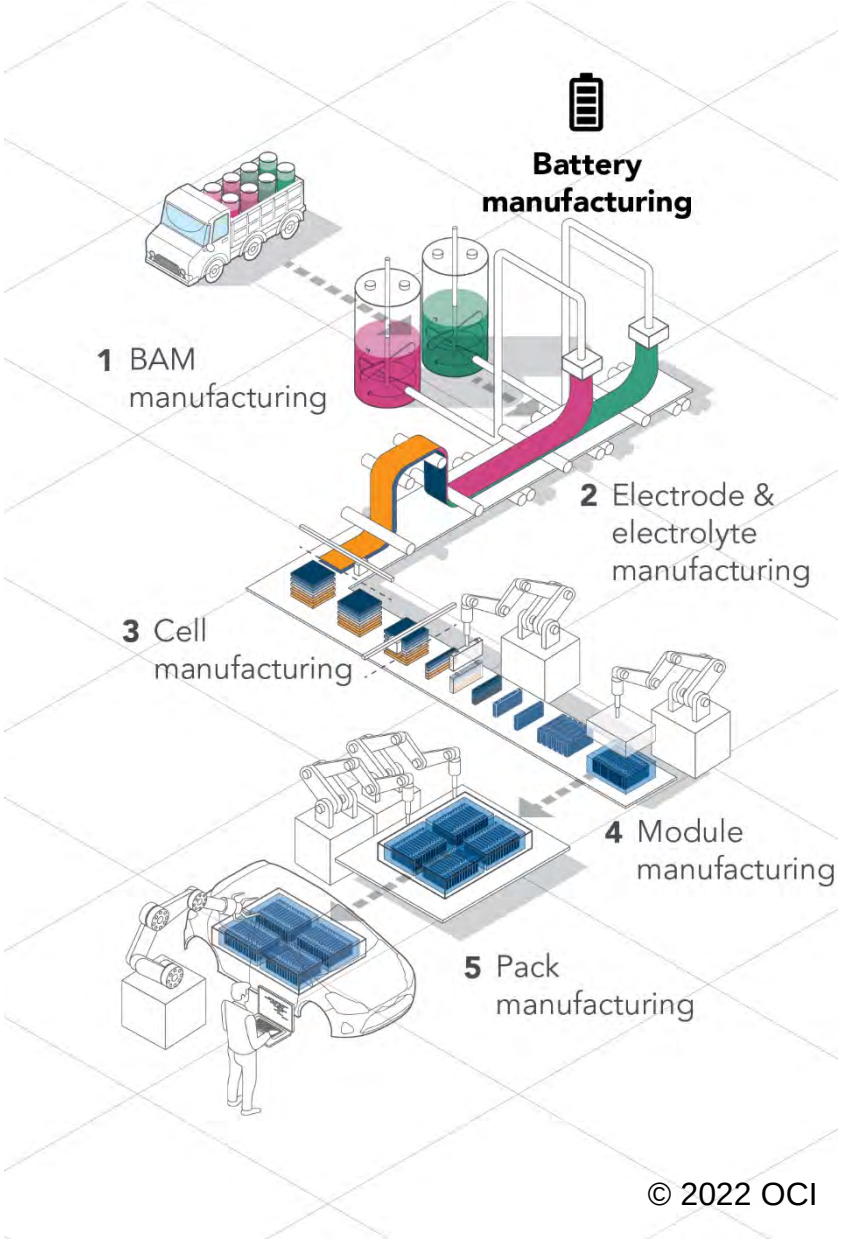
Battery manufacturing usually starts with the production of battery active materials (BAMs), the chemically active elements of a battery. BAMs are manufactured from the battery-grade chemicals produced in the first step of the EV battery lifecycle.[24] Certain BAMs require an interim manufacturing step during which the battery-grade chemicals are converted into precursor materials[25] which are subsequently manufactured into BAMs.[26]

Battery active materials are used to manufacture electrodes and electrolytes,[27] the battery components which enable the flow of electricity.[28] Electrodes and electrolytes are then packaged to form battery cells, the smallest unit within a battery that produces electricity.[29] Several battery cells are packed into cases with terminals to form battery modules, which help protect battery cells from external shocks. Finally, multiple battery modules are joined with electrical connections and cooling equipment to produce the battery packs used in EVs.[30]

As demand for EVs grows, there is a need to ramp-up battery production. Manufacturers working to match supply with demand are increasingly turning to high-volume battery manufacturing facilities called gigafactories ("giga" meaning billions). Gigafactories tend to use digitized, automated procedures to manage complex processes and meet output targets.[31]

Company Highlight: **Stromcore**

Based in Mississauga, Stromcore develops industrial lithium-ion batteries for electric forklifts. Their batteries include a heating system, enabling them to withstand freezing temperatures. At the battery's end of life, Stromcore salvages up to 99% of its components.[32]



Battery manufacturing lifecycle steps

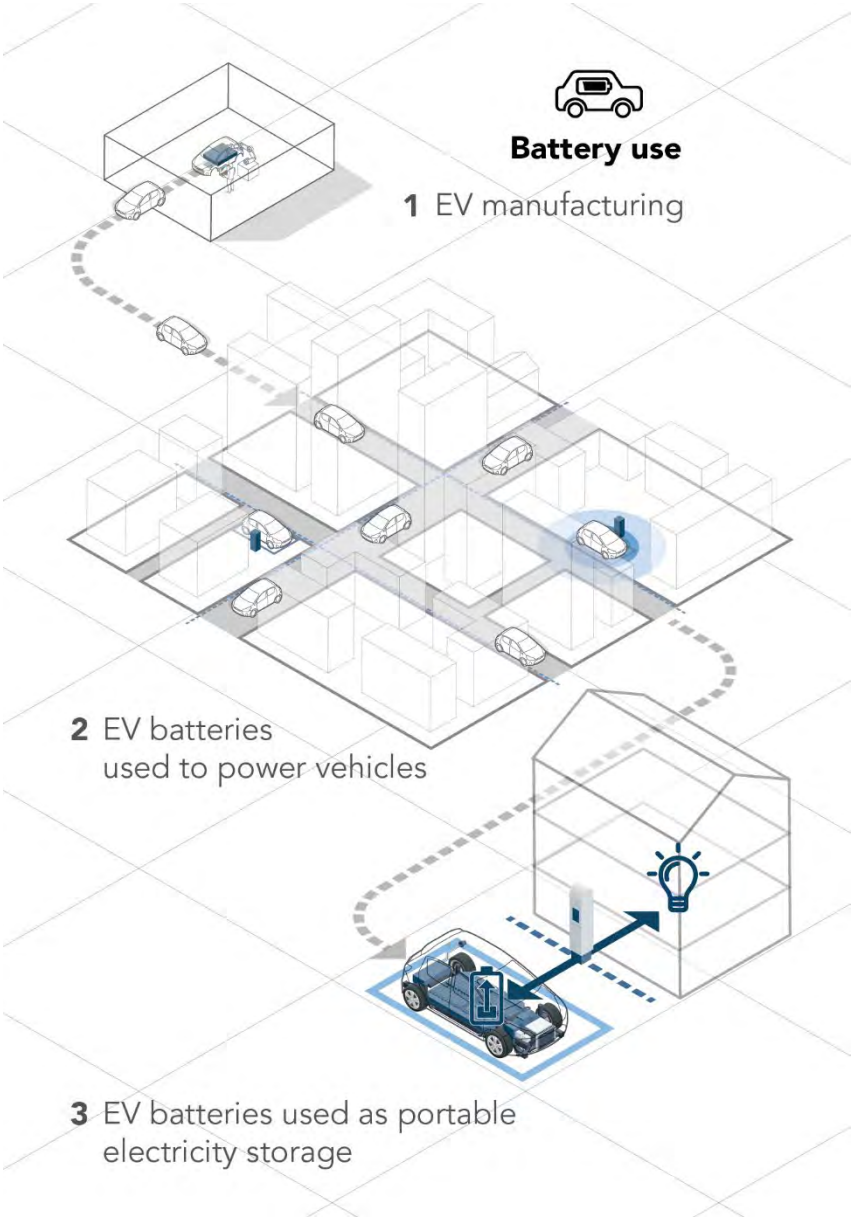
Battery use

Following manufacturing, EV batteries are placed within EVs and made ready for use. During use, EV batteries produce electricity for the primary purpose of powering vehicles. In addition to powering vehicles, EV batteries can also be used for portable electricity storage. For example, EV batteries can provide power to buildings during planned or unexpected outages, replacing stationary diesel generators.[33]

EV batteries are subjected to a series of discharge and charge cycles during use. The number of discharge and charge cycles batteries can undergo before reaching the end of their useful lives is affected by several factors. For example, rapid charging can reduce the length of batteries' useful lives by increasing the rate of degradation.[34]

Company Highlight: **Peak Power**

This Ontario-based climate tech company aims to be at the forefront of the energy transition with vehicle-to-grid technology and battery storage solutions. One of the company's pilot projects, Vehicle-to-Home, will test EVs' ability to provide back-up electricity for homes through simulated events and real-world trials set to take place in Ontario.[35]



Battery use lifecycle steps

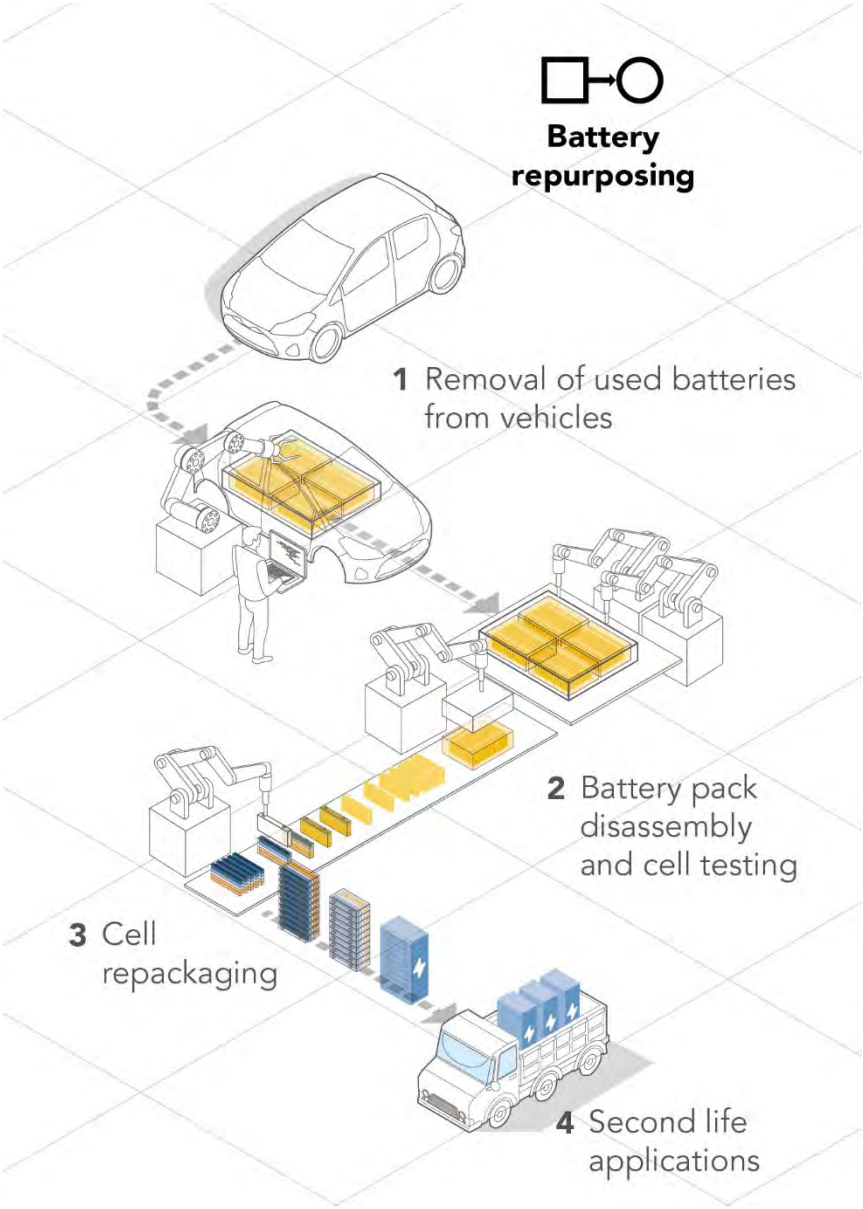
Battery repurposing

Repurposing batteries can help achieve sustainability goals and maximize use of extracted critical minerals by reducing overall greenhouse gas emissions and lowering lifecycle costs. The steps involved in repurposing an EV battery include removing it from the vehicle, disassembling the battery pack, testing the battery cells, and repackaging them into new packs appropriate for their second-life application.[36]

Second-life applications for batteries are often less demanding than EVs. For example, EV batteries may be repurposed for electric bicycles, street lighting, back-up power supply for buildings, or support for renewable energy generation and grids.[37]

Company Highlight: **Electrovaya**

Electrovaya designs, develops, and manufactures battery systems and other battery-related products. Founded in 1996, the Ontario-based company possesses extensive IP to supply safe and long-lasting lithium-ion batteries. The tech-focused company is also partnering with utility companies to develop solutions for clean energy storage using new and re-purposed batteries.[38]



Battery repurposing lifecycle steps

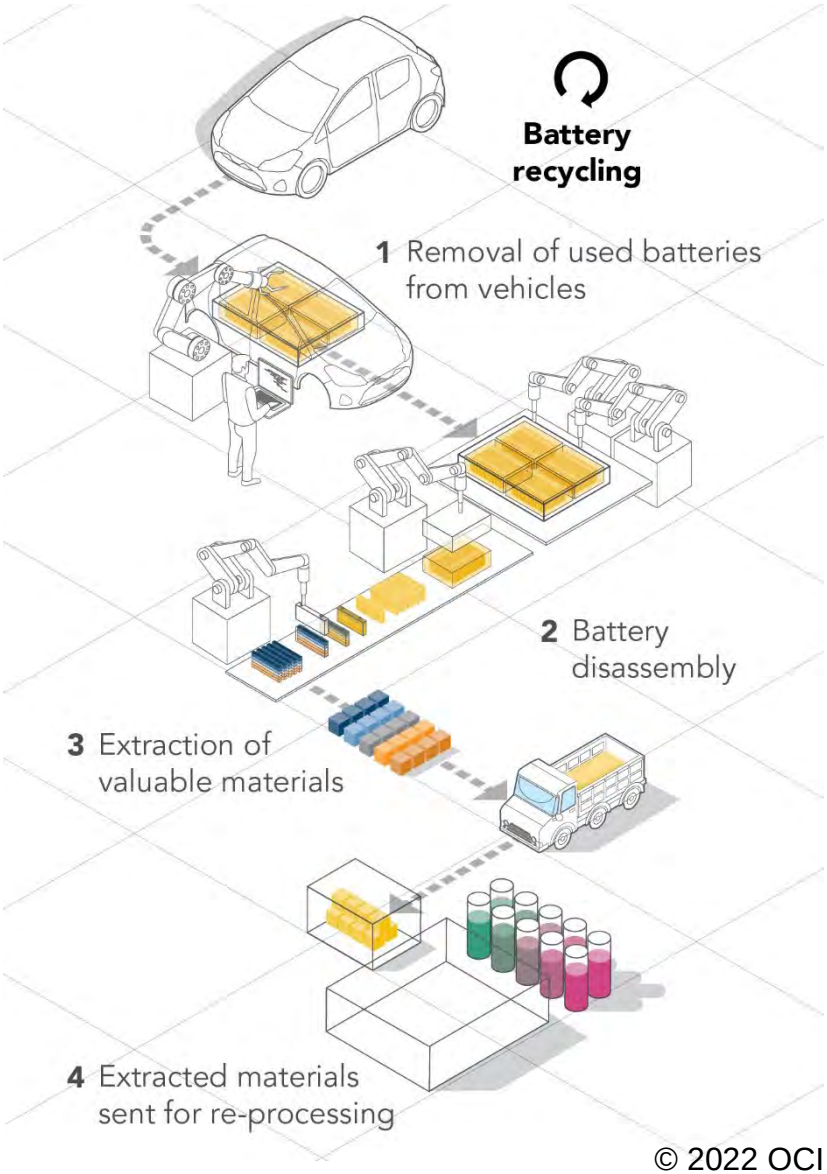
Battery recycling

Recycling batteries, like repurposing batteries, can help minimize the impact of battery production on natural resources and the environment. The steps involved in recycling an EV battery include removing it from the vehicle, disassembling it, extracting the valuable materials, and sending the extracted materials for re-processing.[39]

Currently, less than 5% of all lithium-ion batteries are recycled globally.[40] As the number of EVs on the street increases, lithium-ion battery recycling capabilities must scale-up as well.

Company Highlight: **Li-Cycle**

Headquartered in Toronto, Li-Cycle recycles lithium-ion batteries. Guided by a “circular economy” approach, its critical-mineral-recovery method returns 95% of battery materials to the supply chain. This closed-loop solution aims to decrease the carbon footprint of electric-powered transportation. In May 2020, Li-Cycle Ontario upgraded its capacity to process 5,000 tonnes of lithium-ion batteries annually.[41]

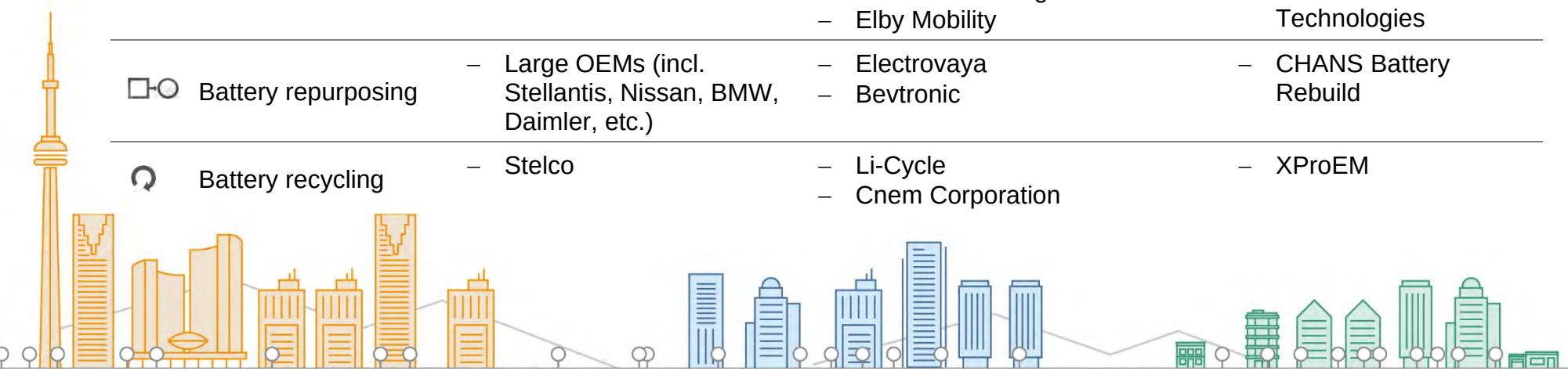


Battery recycling lifecycle steps

Ecosystem players

The end-to-end EV battery lifecycle encompasses a wide range of processes from mineral extraction, processing, and refining to battery recycling. As such, a broad range of actors and players are required to ensure this ecosystem functions cohesively. A selection of ecosystem players in Ontario are highlighted below.

	Multinational enterprises	Small and medium-sized enterprises	Start-ups
Mineral extraction, processing, and refining	– Vale Canada – Glencore	– Avalon Advanced Materials – Frontier Lithium – Electra Battery Materials – Canada Nickel	– Green Graphite – EV Nickel
Battery manufacturing	– Dongshin Motech – Tesla – NextStar Energy – Panasonic Eco Solutions	– Stromcore – Polar Sapphire – Volt Carbon Technologies – AI Materia	– Eecomobility – PhaseShift Technologies – AlumaPower
Battery use	– Nuvation Energy – Eberspaecher Vecture	– Peak Power – Gbatteries – Teviot Technologies – Elby Mobility	– ELeapPower – SpinorX – Electrans Technologies
Battery repurposing	– Large OEMs (incl. Stellantis, Nissan, BMW, Daimler, etc.)	– Electrovaya – Bevtronic	– CHANS Battery Rebuild
Battery recycling	– Stelco	– Li-Cycle – Cnem Corporation	– XProEM



4. Factors Driving Change in the Critical Minerals Sector

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"Ontario’s varied geology provides tremendous opportunities for critical mineral exploration. In fact, Ontario is already a producer of several critical minerals (either as primary commodities or by-products). For other critical minerals, there has been past production in Ontario or these minerals occur in deposits that are currently being developed for possible future production.”[42]

—Mark Puumala, Resident Geologist Program, Ontario Geological Survey

As the clean energy transition progresses, demand for critical minerals is forecasted to increase significantly. In this context, several overarching trends, three of which are detailed below, are shaping the future of the critical minerals sector.

Increasing demand for EVs

The future of transportation is electric. Driven by a desire to reduce greenhouse gas emissions and curb climate change, jurisdictions across the world are encouraging the use of EVs in place of vehicles with internal combustion engines.

In Canada, the federal government is developing a sales mandate requiring that zero-emission vehicles comprise 100% of new light-duty vehicle sales by 2035. The federal government also plans to introduce regulations requiring that 100% of certain medium- and heavy-duty vehicles sold be zero-emission by 2040.[43] To support the uptake of EVs, the Canadian government has invested over $1B through infrastructure programs and purchase subsidies.[44]

In parallel with new government mandates, customer sentiment is warming to EVs. According to KPMG's 2022 Auto Survey, 71% of Canadians would consider buying an EV the next time they purchase a car.[45] Globally, the International Energy Agency predicts that there will be more than 200M EVs on the road by 2030.[46]

"Providing all Ontarians with convenient, public access to fast and reliable charging will help us move towards our goal of making Made-in-Ontario electric vehicles the top choice for both passenger and commercial drivers."[47]

—The Honourable Caroline Mulroney, Ontario Minister of Transportation & Ontario Minister of Francophone Affairs

The need to diversify production

Critical mineral activity is currently highly concentrated in a few countries and companies, which constrains access and reduces resilience.

In 2019, the top three lithium producing countries—Australia, Chile, and China—extracted over 87% of all globally mined lithium.[48] Similarly, 77% of all mined cobalt was extracted by the largest three producing countries of cobalt (the Democratic Republic of the Congo, Australia, and Russia) and 56% of all mined nickel was extracted by the largest three producing countries of nickel (Indonesia, the Philippines, and Russia).[49] Mineral processing is geographically concentrated as well: the share of total processing for which the top three processing countries of lithium (China, Chile, and Argentina), cobalt (China, Finland, and Belgium), and nickel (China, Indonesia, and Japan) were responsible equalled 97%, 80%, and 58%, respectively.[50]

Activity is also concentrated within the hands of a few companies. In 2021, the top three lithium producing companies extracted over 25% of all lithium.[51] Furthermore, the top-three producing companies in battery cell production manufactured well over 50% of all EV battery cell capacity in the same year.[52]

The high level of concentration is bringing attention to the need to diversify critical minerals supply chains to protect against risks such as geopolitical conflicts, price shocks, or trade restrictions.

Shift in focus on environmental, social, and governance considerations

Environmental, social, and governance (ESG) considerations are playing an ever larger role in how companies operate. More and more, consumers want to know that the products they purchase are sustainably and ethically made. This is particularly true of electric-vehicle consumers, who may wish to reduce their own environmental impact through their purchase. According to PwC's 2021 Consumer Intelligence Series survey on ESG, 83% of consumers think companies should be actively shaping ESG best practices while 86% of employees prefer to support and work for companies that support similar issues as themselves.[53]

Factors such as greenhouse gas emissions and waste production during critical mineral extraction and EV battery production are examples of ESG considerations that may impact consumers decisions when purchasing EVs.

> "With EVs, there's a moral calculation – that when you are buying, you expect it to be green."[54]
>
> —The Honourable Victor Fedeli, Ontario Minister of Economic Development, Job Creation and Trade

5. Ontario’s Unique Position

"We know that we can and should build the vehicles of the future right here in Ontario. We have the expertise, we have the best workers anywhere on this planet, we have the critical minerals needed to power the EV vehicle revolution — now we have the competitive business environment needed to attract game-changing global investments."[55]

—The Honourable Doug Ford, Premier of Ontario

Ontario's role as a leader in the critical minerals sector is bolstered by mineral wealth, government support, and private-sector investment. This section elaborates on these factors and others to explain the province's unique position in the EV battery supply chain.

Access to minerals

Ontario has access to a large supply of naturally occurring minerals. There are currently 37 active mining operations throughout the province, 10 of which produce critical minerals.[56] As of March 2022, the province was home to approximately 130 early exploration stage critical minerals projects and 16 advanced exploration stage critical minerals projects.[57] Several of these mines and projects extract, or are exploring opportunities to extract, cobalt, copper, nickel, graphite, and lithium, critical minerals that are essential for EV batteries.[58]

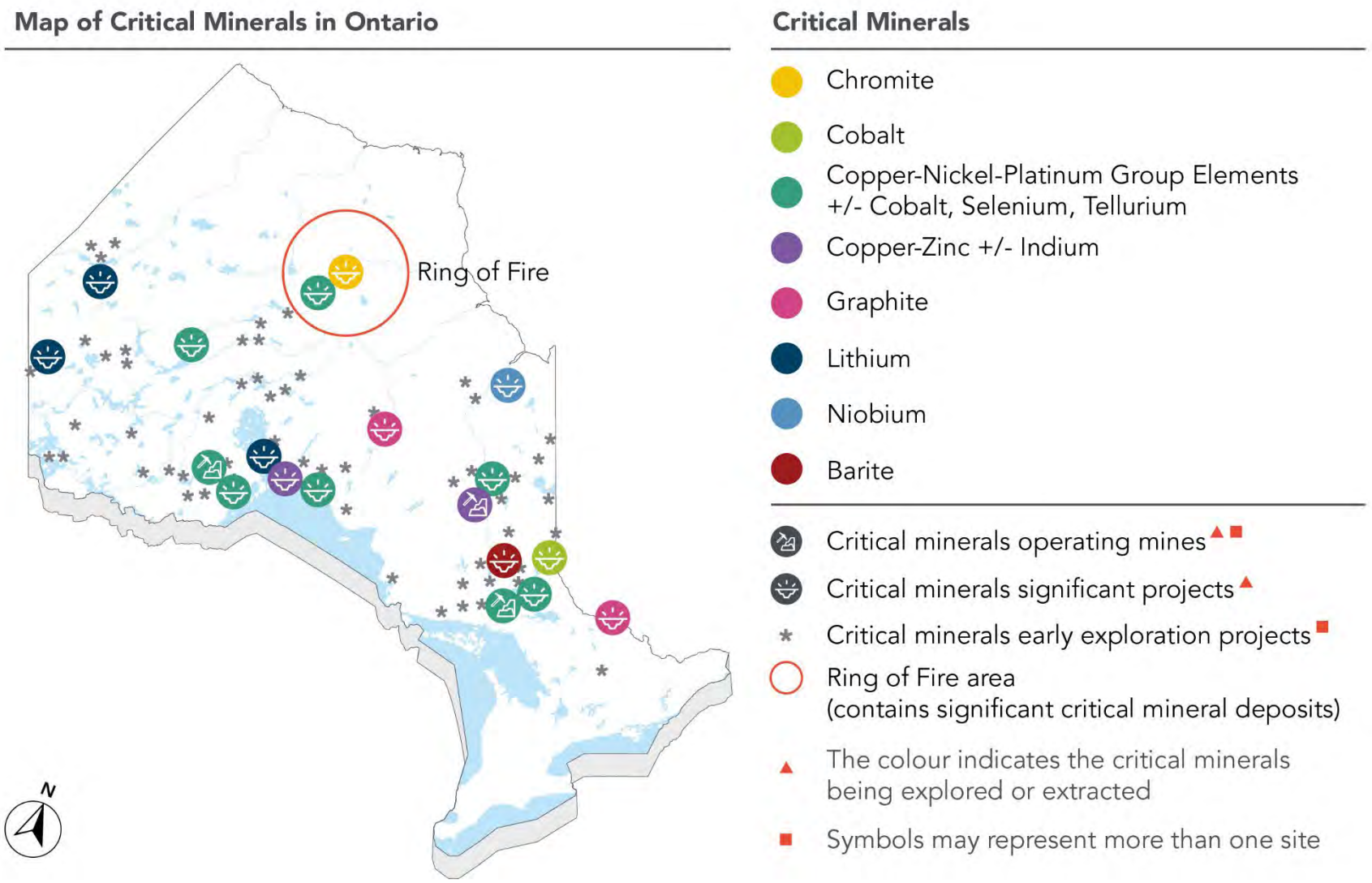
According to the 2021 preliminary mineral production estimates, Ontario is Canada's third largest mineral producer.[59] In 2021, Ontario produced $11.1B worth of minerals, which comprised 20% of Canada's total mineral production. In the same year, Ontario produced 30% of the country's cobalt, 24% of its copper, and 36% of its nickel.[60]

Ontario's mining operations are only expected to grow in coming years. In 2025, the province's total value of mineral production is predicted to reach $13.7B.[61] The province has made several commitments in its Critical Mineral Strategy to support the mining sector, including providing easier access to geoscience data and undertaking new geoscience initiatives in partnership with Indigenous communities.[62]

Several other Canadian provinces extract large quantities of minerals as well, increasing the amount of domestic minerals which Ontario can leverage for downstream EV battery production. In 2021, Canada ranked fifth worldwide and first in North America in raw materials.[63]

Ontario's Ring of Fire region—covered by the James Bay Treaty (Treaty No. 9)[64]—is about 5,000 square kilometres and is located northeast of Thunder Bay.[65] It has various critical minerals, including copper, cobalt, and nickel, that can be purposed for a variety of uses, including EVs.[66] Developing this region could help build a domestic supply chain of several critical minerals.[67]

Preliminary steps, like social and environmental impact assessments for a proposed all-season road towards the Ring of Fire are being led by First Nations in the region, such as Marten Falls First Nation and Webequie First Nation.[68] Numerous steps remain, including securing funding for the access road, addressing environmental and sustainability considerations, and reaching agreement among actors.[69] The development of thoughtful, co-designed solutions presents an opportunity to advance reconciliation efforts and create a mutually prosperous relationship.[70]



Overview of critical minerals operating mines, critical minerals significant projects, and critical minerals early exploration projects in Ontario[71]

Regulatory and policy framework

Ontario combines a robust regulatory framework that ensures social and environmental health with mechanisms to streamline approval processes.

Mining projects in Ontario are subject to the regulations of the Ontario Mining Act, the Environmental Assessment Act, the Environmental Protection Act, the Ontario Water Resources Act, the Public Lands Act, and the Occupational Health and Safety Act throughout exploration, development, operation, and closure.[72] These regulations ensure health, safety, and protection of the natural environment while remaining efficient and responsive to project needs.

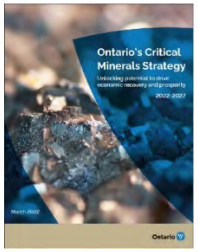
Most critical minerals are located in northern Ontario in proximity to many Indigenous communities, triggering a legal duty to consult.[73] Canada and Ontario have adopted the United Nations Declaration on the Rights of Indigenous Peoples into legislation, thereby enhancing the responsibility to recognize and value the rights of Indigenous Nations and Peoples and conduct relations in a manner that is built on the foundation of respect, trust, and collaboration.[74]

To streamline its mine development review process and help clarify and coordinate permits and approvals from multiple ministries or levels of government, Ontario offers a One Window Coordination Process that defines the roles of the proponent and the government, enables efficient project planning, and supports timely review of new projects.[75] Ontario has also recently updated the Mining Act to provide transparency around processing timelines for closure plan amendments, a move that will help boost certainty for businesses.[76]

In addition to its streamlined regulatory processes and reputation for environmental protection, Ontario's general "open for business" attitude provides further support for companies located in the province. For example, Ontario provides electricity to mining and manufacturing companies at reduced costs through the Northern Energy Advantage Program[77] and the Comprehensive Electricity Plan.[78]

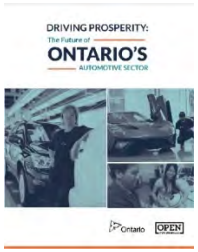
The provincial and federal governments have released several action plans and strategies that reflect the generally positive regulatory environment and governmental commitment to developing critical mineral mining, battery assembly, and EV production. Some key documents include Ontario's Critical Mineral Strategy;[79] the Canada-U.S. Joint Action Plan on Critical Minerals Collaboration;[80] Canada's Critical Mineral Strategy;[81] Driving Prosperity: The Future of Ontario's Automotive Sector (Phase 1);[82] and Driving Prosperity: Ontario's Automotive Plan (Phase 2).[83]

Ontario’s Critical Minerals Strategy 2022–2027



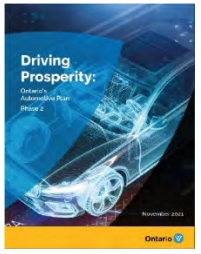
Presents a five-year roadmap for the critical minerals sector, with specific initiatives around mineral exploration, processing & supply chains, regulatory framework, research, development of opportunities with Indigenous partners, and the skilled labour force.

Driving Prosperity Phase 1



Presents Ontario's plan to position itself as a North American hub for advanced auto manufacturing through a focus on fostering partnerships, planning for the future decade, leveraging assets, and maintaining accountability.

Driving Prosperity Phase 2

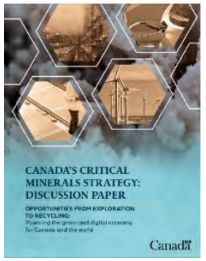


Outlines actions to support the development of electric, autonomous, and connected vehicles and the expansion of an EV supply chain that includes the exploration and production of critical minerals.

Canada-U.S. Joint Action Plan on Critical Minerals

Guides cooperation between Canada and the U.S. in areas such as industry engagement, information sharing, research and development, and securing supply chains.

Canada's Critical Minerals Strategy



Currently in draft phase, highlights the need to drive research, accelerate project development, build sustainable infrastructure, advance Indigenous reconciliation, grow a diverse workforce, and strengthen global leadership.

A selection of key action plans and strategies that support critical minerals mining, battery assembly, and EV production.

Government investments

Municipal, provincial, and federal governments are advocating strongly for the development of an end-to-end battery supply chain in Ontario and, more broadly, in Canada. Governments have shown this commitment through investments in private-sector mining companies and support for EV battery research and development (R&D).

In 2020, the provincial and federal governments invested a combined $10M in Electra Battery Materials Corporation to help establish the first battery-grade cobalt refinery in North America.[84] More recently, Ontario invested an additional $250,000 to support the company's efforts to develop a battery materials park which is planned to include the previously announced cobalt refinery as well as a nickel sulphate production plant, a battery recycling facility, and a battery precursor materials plant. The creation of this park will co-locate several stages of the EV battery lifecycle, creating a shorter supply chain.[85]

In 2020, the federal government launched the Net Zero Accelerator Initiative, which will provide $8B in funding to expedite decarbonization projects, including those related to battery innovation.[86]

At the provincial level, Round 11 of the Ontario Research Fund Research Excellence program is providing up to $2M for applicants whose work supports the Critical Minerals Strategy and the Ontario Vehicle Innovation Network. Funding will go to applications spanning the entire automotive value chain, including connected autonomous vehicles (CAVs), EVs, battery and powertrain technology, and industrial/mining technologies.[87]

> "As we secure game-changing investments, we're also connecting resources, industries and workers in northern Ontario with the manufacturing might of southern Ontario to build up home-grown supply chains. Every region of Ontario will benefit with thousands of jobs being created and a stronger economy that works for everyone."[88]
>
> —The Honourable Doug Ford, Premier of Ontario

Private-sector investments

Recent private-sector investments in mining are fostering Ontario's EV battery supply chain. For example, Frontier Lithium, owner of two lithium deposits in northwest Ontario large enough to produce almost 500,000 EV batteries per year,[89] is aiming to supply lithium hydroxide and lithium salts for battery production in North America.[90] The company is currently completing the tests and studies necessary to develop a mine, mill, and lithium chemical processing plants.[91]

Company Highlight: **Umicore**

Umicore, a multinational enterprise focused on circular materials technology, has announced a $1.5B investment in the Province of Ontario.[92] The investment will fund a large-scale battery active materials manufacturing facility in Loyalist, expected to start operation towards the end of 2025. The manufacturing of these materials will create a valuable link in Canada's battery value chain for electric mobility.[93]

Private-sector investments are also helping the province position itself as a leader in battery research and innovation. In February 2022, auto parts producer Flex-N-Gate announced $18.5M in funding to open the Flex-Ion Battery Innovation Centre. The centre will be outfitted with a pilot production line and employ 18 battery engineers and scientists collaborating with college and university researchers to develop new battery technologies suited for EVs.[94]

Ontario's capacity for battery manufacturing is expanding as well. In March 2022, LG Energy Solution, a leading battery manufacturing company, and Stellantis, a large automaker, announced a joint venture to invest $4.9B to create Canada's first EV battery gigafactory in Windsor, Ontario. Once operational, the factory is expected to provide 2,500 jobs likely to attract new talent.[95] Following the announcement of the new gigafactory, DongShin Motech, an automotive parts supplier, announced its intention to open a $90M plant in Windsor to supply the new gigafactory with aluminum battery casings.[96]

Additional investments made by members of Ontario's automotive ecosystem include a $1.8B investment by Ford Motor Company to build a new battery-electric-vehicle (BEV) manufacturing facility in Oakville, Ontario and a $1B investment from General Motors Company to manufacture its new electric van in Ingersoll, Ontario.[97]

"Our joint venture with LG Energy Solution is yet another stepping stone to achieving our aggressive electrification roadmap in the region aimed at hitting 50 per cent of battery electric vehicle sales in the U.S. and Canada by the end of the decade. We are grateful to the municipal, provincial and federal levels of government for their support and commitment to help position Canada as a North American leader in the production of electric vehicle batteries."[98]

—Carlos Tavares, CEO of Stellantis

Research & development

Ontario is positioning itself as a global leader in R&D for mining and EV battery production. The province's R&D initiatives are bolstered by a large supply of local talent. Ontario graduates 63,500 students in science, technology, engineering, and mathematics (STEM) fields each year[99] and has a history of collaboration between private-sector, public-sector, and academic institutions.

Numerous research centres, development sites, and innovation networks are located within Ontario, helping to spur innovation and commercialize new technologies. For example, the Ontario-based Centre for Excellence in Mining Innovation works to advance commercially viable innovations to improve mining operations.[100] In 2021, the Centre for Excellence in Mining Innovation helped to launch the Mining Innovation Commercialization Accelerator which provides funding to support the development of new technologies that can increase mine capacity, reduce mine energy consumption and emissions, enable the implementation of autonomous mining systems or minimize environmental risk.[101] Ontario is also home to the CanmetMATERIALS lab, a facility in Hamilton dedicated to the creation and evaluation of metals and materials used for energy, transportation, and manufacturing sectors.[102]

Academic research groups around the province are also advancing EV battery technology. Researchers at the University of Toronto Electric Vehicle Research Centre are studying the transition of EV batteries to second-life applications, including as backup energy sources in microgrids or support services for the power grid.[103]

At the University of Windsor, researchers in the Centre for Hybrid Automotive Research and Green Energy Lab are conducting battery-to-powertrain-to-wheels research and simulating and testing EVs to gain practical insights that can inform EV development.[104] In 2021, researchers at the University of Waterloo were awarded $2M from the federal government's Canada Foundation for Innovation to create the Ontario Centre for Battery and Electrochemical Research, which is expected to become a new hub of electrochemical storage research and collaboration among academics, government agencies, and industry partners.[105]

In line with the collaborative nature of Ontario's automotive ecosystem, a new Northern Ontario Regional Technology Development Site will bring together academic institutions, regional innovation centres, incubators and accelerators, municipal and regional governments, and industry partners to support the development and testing of new automotive technology. The test site will bridge Ontario's mining and manufacturing sectors, helping to expand capabilities throughout the entirety of the EV supply chain.[106]

As part of the Critical Mineral Strategy, Ontario has committed to support further R&D by, among other initiatives, improving mineral recovery from EV batteries, exploring new options for incentivizing critical minerals R&D, and building mineral testing capacity and small-scale processing through collaboration with academic institutions and mining companies.[107]

Through the Ontario Vehicle Innovation Network, the province also funds R&D led by SMEs, providing up to $1M of funding to support demonstration, validation, testing and piloting for EV and battery-focused projects.[108]

Ontario is also a partner in Project Arrow, an initiative launched by the Automotive Parts Manufacturers' Association to develop and build the first all-Canadian, zero-emission vehicle. In addition to accelerating EV technology domestically, Project Arrow aims to highlight Ontario's role as an advanced manufacturing hub, support collaboration, increase R&D, and encourage talent development.[109]

> "This lighthouse project [Project Arrow] is highlighting hundreds of advanced technology companies around the world and will serve as the calling card for the next generation of leadership in Canadian zero emissions mobility."[110]
>
> —Flavio Volpe, President, Automotive Parts Manufacturers' Association

Environmental, social, and governance commitments

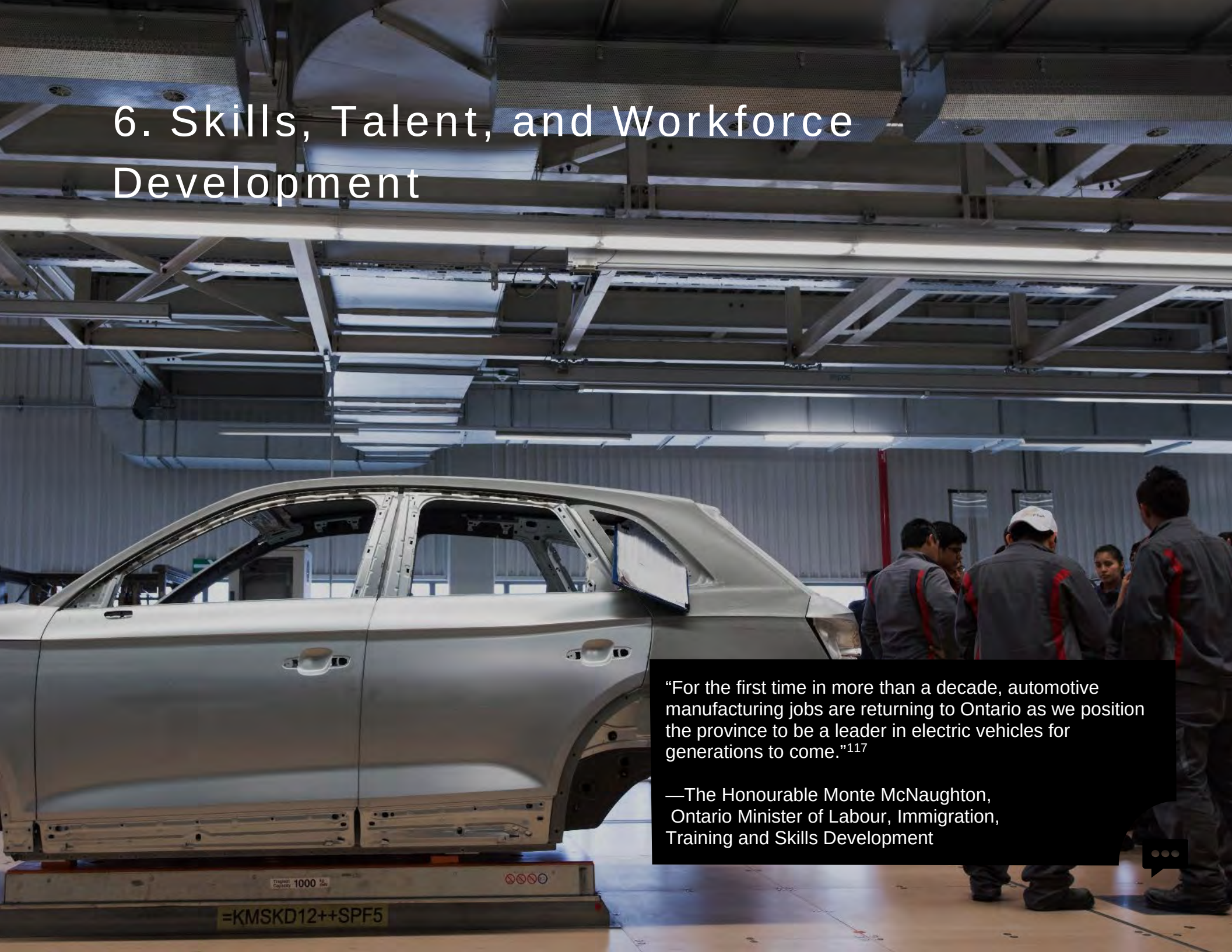
The Canadian mining sector is recognized as a world leader in environmentally friendly and socially responsible practices. The Canadian mining sector uses the Mining Association of Canada's "Towards Sustainable Mining" initiative to ensure responsible mining through a commitment to accountability, transparency, and credibility. Since its creation, several other countries around the world have adopted Canada's "Towards Sustainable Mining" initiative as well.[111]

In Ontario, over 75% of the Ontario Mining Association's members noted that ESG considerations are an important part of operational decisions.[112] Ontario's mining sector is a large user of clean technologies. The province is home to Canada's first all-electric underground mine, which mitigates negative impacts to the health of the mine's employees and the surrounding environment.[113] Additionally, more than three-quarters of mining companies in Ontario are lowering greenhouse gas emissions by participating in carbon pricing schemes.[114]

The rest of the EV supply chain is driven by sustainability as well. Ontario's clean-electricity grid helps companies achieve sustainability targets; in fact, 94% of Ontario's electricity system was emissions-free in 2020.[115] Moreover, by working to develop a domestic EV ecosystem, the province is reducing the amount of emissions produced by transporting intermediate and final products throughout the EV supply chain from mines, to refineries, to manufacturing facilities, to customers.

The province has also committed to collaborating with private-sector partners to develop novel recycling methods for minerals in batteries, promoting a circular economy approach for EVs.[116]

6. Skills, Talent, and Workforce Development



"For the first time in more than a decade, automotive manufacturing jobs are returning to Ontario as we position the province to be a leader in electric vehicles for generations to come."[117]

—The Honourable Monte McNaughton,
Ontario Minister of Labour, Immigration,
Training and Skills Development

Ontario is looking to extend the advantages described above by investing in skills, talent, and workforce development. The following sections detail workforce development initiatives led by the province and by OVIN. It also highlights programs seeking to improve the workforce's equity, diversity, and inclusion.

Ongoing provincial workforce initiatives

Committed to innovation, the province is transforming its facilities and investing in its labour force to cement its role as a global leader. Ontario already has a large, highly skilled workforce spanning the mining and automotive sectors. As of March 2022, over 96,000 workers were directly employed in Ontario's automotive sector, including vehicle assembly and parts production.[118] As of June 2022, mining employed over 20,000 people in Ontario.[119]

With several recently announced refineries and production facilities expected to open in coming years, graduates from Ontario's 19 post-secondary mining programs[120] and 36 post-secondary automotive programs[121] will play a crucial role in filling new positions. Experts predict that the national mining sector will require between 30,000 and 48,000 new workers between 2020 and 2025.[122] In Ontario alone, the automotive industry is expected to need nearly 40,000 new workers by 2030.[123]

The mining and automotive sectors are undergoing change in response to the clean energy transformation. The adoption of new technologies is precipitating demand for specialized skillsets across both sectors. Locally, over 40% of Ontario's mining businesses are leveraging advanced technology and 19% are using emerging technologies, including integrated Internet of Things systems; artificial intelligence; or virtual, mixed, and augmented reality.[124] As use of new technologies grows, skills in data science, machine learning, artificial intelligence, software development, computer-aided design, cybersecurity, mechatronics engineering, equipment maintenance and more are expected to grow in demand.[125]

In planning for the future, Ontario has launched a series of initiatives to expand the workforce to meet expected demand and train or retrain students and employees with the skills needed to succeed in future positions by investing in a range of programs, as described below.

- Ontario is growing the Specialist High Skills Major program through an investment of almost $40M over three years. The program allows high school students to learn about skilled trade positions and acquire relevant skills.[126]
- In 2021, Ontario supported the Indigenous Workplace Development Program through an investment of $3.6M. The program provided construction and mining training to 150 Indigenous community members in support of the opening of a new mine in Geraldton, Ontario.[127]
- Ontario invested $19M into the Career Ready Fund's Auto Stream to increase experiential learning opportunities in Ontario's auto manufacturing and advanced manufacturing sectors.[128]

- In 2019, Ontario invested $3M in a RapidSkills pilot, which provides high-quality, short-duration training to help laid-off, at-risk, and underutilized workers gain new skills for the automotive and advanced manufacturing industries.[129]
- In 2020, Ontario announced a three-year, $59.5M investment in micro-credentials to help retrain people with in-demand skills.[130] $15M was invested into the Micro-Credentials Challenge Fund to fund over 65 projects at colleges, universities, Indigenous Institutes, and private career colleges.[131] The remainder of the funds are dedicated to creating an online portal to access micro-credential training opportunities, a public awareness campaign, expanding the Ontario Student Assistance Program to include micro-credential programs, and creating a system to track learning experiences.[132]
- In February 2021, Ontario provided Skills Development Funding to 146 organizations to fund projects addressing challenges to hiring, training, or retraining workers during the early stages of the COVID-19 pandemic.[133]

Upcoming provincial workforce initiatives

In addition to the existing programs and initiatives described in the preceding section, Ontario has committed to a range of additional workforce development programs. Some commitments include, but are not limited to:

- Financial assistance to support local employment development and human resource planning;[134]
- Support for culturally appropriate experiential student training;[135]
- Promotion of mining careers to encourage participation in mining training programs;[136] and
- Support for immigration pathways for foreign workers and international students.[137]

"With the support of the federal and provincial government, Ford of Canada is investing in the future of its Ontario-based operations, solidifying its commitment to providing thousands of well-paying jobs in Ontario and becoming the first automaker in the country to build full battery-electric vehicles while delivering operational improvements that will maximize production flexibility to ensure we remain operationally competitive."[138]

—Dean Stoneley, Former President and CEO of Ford Motor Company of Canada (2019 – 2021)

Equity, diversity and inclusion workforce initiatives

Equity, diversity, and inclusion (EDI) is an integral part of ensuring that Ontario creates and retains sustainable talent pools for the future of the mining and automotive sectors. Currently, women and immigrants are underrepresented in the mining sector.[139] While there are high rates of Indigenous participation in the mining sector, there are still opportunities to increase involvement, as noted in the Critical Mineral Strategy.[140] The Talent Strategy & Roadmap for Ontario's Automotive and Mobility Sector also found that more work needs to be done to foster equity, diversity, and inclusion within the sectors.[141]

The province has proposed a series of initiatives to improve employment of underrepresented groups in the mining and automotive sectors that include, but are not limited to:

- A review of the automotive and mobility sector's existing talent attraction and development programs in partnership with underrepresented communities to identify opportunities for co-designing to address community-specific barriers;[142]
- Support for the mining industry's efforts to hire underrepresented workers;[143]
- Promotion of programs in the mining sector that encourage Indigenous-owned business, workforce, and skills development;[144] and
- Creation of educational tools in partnership with Indigenous communities that highlight the critical mineral sector's opportunities.[145]

There are also independent organizations that work towards diverse workforce development. For example, the Mining Industry Human Resources Council released a Guide for Aboriginal Communities to create awareness about mining employment, training requirements, and resources available to help enter the minerals and metal sector.[146] The Mining Industry Human Resources Council also has initiatives to support gender equity and provide cultural awareness training.[147]

OVIN workforce initiatives

As part of its mandate, OVIN supports a range of skills, talent, and workforce development initiatives. Key examples of these initiatives are described below.

- OVIN offers two talent development programs: the TalentEdge Fellowship Program[148] (for recent PhD graduates) and the TalentEdge Internship Program[149] (for current students or recent graduates from an undergraduate or Master's program). Both programs provide mentorship opportunities and hands-on, industry-driven experience for current or recent students while enabling access to talent for Ontario companies.
- OVIN developed a Skills & Career Navigator tool to help people at various stages in their career learn about different sub-areas within the automotive industry, including relevant technical and non-technical skills, course-based and experiential learning opportunities, and potential jobs and career resources.[150]
- OVIN's Talent Strategy & Roadmap identifies four objectives and nine initiatives to help train and retrain the province's automotive and mobility workforce for the jobs of the future.[151]
- OVIN is developing a made-in-Ontario Upskilling Platform for the automotive and mobility sector. The platform will enable wider access to Ontario training and educational programs and will promote Ontario's ecosystem to the global market.[152]

7. Opportunities to Further Strengthen Ontario's Position as a Leader in the EV Battery Supply Chain

"Ontario's wheels are in motion to create a more sustainable future for the transportation sector. A critical pillar in our plan is strengthening Ontario's position as an electric vehicle production hub, making these vehicles more accessible to drivers across the province. Our new flagship program will go a long way towards supporting our talented workforce, driving electric vehicle research and development, and reducing greenhouse gas emissions."[153]

—The Honourable Caroline Mulroney, Ontario Minister of Transportation & Ontario Minister of Francophone Affairs

As demand for critical minerals and EVs expands, global market resiliency is becoming increasingly important. Ontario is well-positioned to leverage its existing strengths not only to support industry stability and resiliency, but also to foster and secure its own position as a leader in the end-to-end EV battery lifecycle. The following sections cast a light on some of the immediate opportunities to continue the development of Ontario's thriving domestic EV ecosystem.

Expand repurposing and recycling capacities

Ontario has an opportunity to drastically expand lithium-ion battery repurposing and recycling capacities. In line with ESG considerations, recycling and repurposing batteries is critical to reducing waste. However, recycling capacities for lithium-ion batteries are currently low, with less than five precent recycled globally.[154] As demand for EVs increases, so will the number of batteries to be recycled each year.

The province has committed to incentivizing recycling as part of broader support for a domestic battery supply chain. Ontario's Critical Mineral Strategy notes that there is a need for additional research on the technology that enables EV battery recycling. The province intends to improve mineral recovery from EV batteries and collaborate with industry partners developing critical minerals recycling processes.[155]

Increase minerals access and bolster production

Whenever possible, demand for critical minerals should be met using recycled materials to decrease the impact of mining on the environment. However, due to long cycle lives and growing demand for EVs, recycled EV batteries alone will not supply enough critical minerals to satisfy demand in the near future.[156] As such, increasing the capacity of existing mines and establishing new mines will be essential to meeting demand projections.

To capitalize on its access to a wide range of minerals, Ontario is encouraging the establishment of new mines through the Ontario Junior Exploration Program. As part of this initiative, non-producing junior mining companies can be granted up to $200,000 to cover exploration costs.[157] As part of its Critical Mineral Strategy, the province has committed to improving its regulatory framework by considering less burdensome regulatory pathways for lower-impact mining projects and by adding transparency for decision-making criteria.[158] This approach will create new investment opportunities, while ensuring stringent environmental protections and robust community engagement.

Establishing mines, however, is a slow process and has a relatively large impact on the environment. To be able to

more immediately meet demand, the province may also seek to encourage increased mine productivity and reduced mineral loss through waste. As part of its Critical Mineral Strategy, the province has committed to exploring opportunities to recover minerals from mine waste, to developing a regulatory framework that enables mineral recovery from mine tailings and waste, and to aligning the new framework with existing regulatory requirements.[159]

Expand refining, processing, and manufacturing capacities

Ontario can leverage recent announcements of planned investments in mineral refining and processing and battery production to encourage additional expansion of its midstream processing and downstream manufacturing capacities. Ontario—like the rest of Canada—has not yet maximized its potential participation in the stages of the EV battery supply chain between mineral extraction and EV battery installation.[160] Despite access to many battery materials, Ontario does not currently produce battery-grade nickel, cobalt, manganese, graphite, or lithium.[161] (A battery-grade cobalt sulphate refinery is, however, under development in Ontario[162] and the potential for a battery-grade nickel sulphate refinery is being studied.[163]) The province also recognized a need to grow its battery manufacturing facilities. Several are expected to open in the next few years, including, among others, Stellantis and LG Energy Solution's battery cell manufacturing plant,[164] DongShin Motech's aluminum battery casing plant,[165] and Umicore's battery active material plant.[166] By continuing to increase its domestic processing and production capacity, Ontario can capitalize on high-value stages of the EV battery lifecycle while developing an increasingly independent supply chain that is less susceptible to risk.

Increasing local mineral processing and battery manufacturing capacities would also reduce the carbon footprint of Ontario-made batteries, since international shipping of the heavy battery materials requires more greenhouse gas emissions than short-distance domestic transportation.

Promote collaboration

Ontario can promote collaboration amongst start-ups, SMEs, MNEs, academic institutions, research centres and other stakeholders spanning the automotive and mining sectors to increase knowledge sharing, capacity building, and productivity within the EV battery supply chain.

The entire EV battery supply chain is highly integrated. Changes in mineral availability may affect the preferred chemistries for EV batteries, which in turn may impact feasible recycling methods. Enhanced collaboration across all actors of the EV battery supply chain can help facilitate improved decision making and increased flexibility, resulting in higher efficiency and enhanced offerings.

Ontario already has a large network of mining and automotive actors. As the province looks to develop a fully domestic EV battery supply chain, increasing collaboration amongst these actors while leveraging their diverse capabilities will become increasingly important.

“With recent success attracting major investments to the province, our government is staking Ontario's claim to developing and building the batteries that will power vehicles of the future." [167]

—The Honourable Victor Fedeli, Ontario Minister of Economic Development, Job Creation and Trade

8. About OVIN

The **Ontario Vehicle Innovation Network (OVIN)** is a key component of Driving Prosperity, the Government of Ontario's initiative to ensure that the automotive sector remains competitive and continues to thrive. The Government of Ontario has committed $56.4M for OVIN over the next four years to support research and development (R&D) funding, talent development, technology acceleration, business and technical support, and testing and demonstration sites. OVIN programs support small- and medium-sized enterprises (SMEs) to develop, test, and commercialize new automotive and mobility products and technologies, and cultivate the capacity of a province-wide network to drive future and green mobility solutions, reinforcing Ontario's position as a global leader.

OVIN, led by Ontario Centre of Innovation (OCI), is supported by the Government of Ontario's Ministry of Economic Development, Job Creation and Trade (MEDJCT) and Ministry of Transportation (MTO).

The initiative comprises five distinct programs and a central hub.

The OVIN programs are:

- Research and Development Partnership Fund
- Talent Development
- Regional Technology Development Sites
- Demonstration Zone
- Project Arrow

The OVIN Central Hub is the driving force behind the programming, province-wide coordination of activities and resources, and Ontario's push to lead in the future of the automotive and mobility sector globally. Led by a dedicated team, the Central Hub provides the following key functions:

- A focal point for all stakeholders across the province;
- A bridge for collaborative partnerships between industry, post-secondary institutions, broader public sector agencies, municipalities, and the government;
- A concierge for new entrants into Ontario's thriving ecosystem; and
- A hub that drives public education and thought leadership activities and raises awareness around the potential of automotive and mobility technologies and the opportunities for Ontario and for its partners.

To find out the latest news, visit www.ovinhub.ca or follow OVIN on social media @OVINhub

OVIN Objectives

Foster the development and commercialization of Ontario-made advanced automotive technologies and smart mobility solutions

Showcase the Province of Ontario as the leader in the development, testing, piloting and adoption of the latest transportation and infrastructure technologies

Drive innovation and collaboration among the growing network of stakeholders at the convergence of automotive and technology

Leverage and retain Ontario’s highly skilled talent, and prepare Ontario’s workforce for jobs of the future in the automotive and mobility sector

Harness Ontario’s regional strengths and capabilities, and support its clusters of automotive and technology

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10. Abbreviations

BAM	Battery active materials
BEV	Battery-electric vehicle
CAV	Connected autonomous vehicle
EDI	Equity, diversity, and inclusion
ESG	Environmental, social, and governance
EV	Electric vehicle
MEDJCT	Ministry of Economic Development, Job Creation and Trade
MLITSD	Ministry of Labour, Immigration, Training and Skills Development
MNE	Multinational enterprise
MTO	Ministry of Transportation Ontario
OCI	Ontario Centre of Innovation
OEM	Original equipment manufacturer
OVIN	Ontario Vehicle Innovation Network
R&D	Research and development
SME	Small and medium-sized enterprise
STEM	Science, technology, engineering, and mathematics

11. Disclaimer

This report was commissioned by the Ontario Centre of Innovation (OCI) through a Request for Proposals titled “Ontario Vehicle Innovation Network (OVIN) – Annual Comprehensive Sector Report & Quarterly Specialized Reports,” dated April 26, 2022, and has been prepared by Arup Canada Inc.

In preparing this report, we have relied on information provided by others, and we do not accept responsibility for the content, including the accuracy and completeness, of such information.

We emphasize that any forward-looking projections or forecasts are based upon interpretations or assessments of available information at the time of writing this report. Therefore, readers and recipients of this report should not place undue reliance on the report and are cautioned to perform their own due diligence, investigations, and analysis before placing reliance on it.

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